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STUDIES OF THE NATURE AND CONTROL OF BLIGHT, LEAF AND POD SPOT, AND FOOTROT OF PEAS CAUSED BY SPECIES OF ASCOCHYTA

LEON K. JONES

IMPERIAL BUREAU OF MYCOLOGY

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PLATE I.—CULTURES OF SPECIES OF ASCOCHYTA PARASITIC ON THE PEA.

A. *Mycosphaerella pinodes* (Berk and Blox.) Stone.
B. *Ascochyta pisi* Lib.
C. *Ascochyta pinodella* n. sp.

(Organisms grown on oat agar slants and photographed after ten days incubation at 18° C.)

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STUDIES OF THE NATURE AND CONTROL OF BLIGHT, LEAF AND POD SPOT, AND FOOT-ROT OF PEAS CAUSED BY SPECIES OF ASCOCHYTA

LEON K. JONES

ABSTRACT

The confusion in literature relative to the causal agent of the disease known as Ascochyta blight or Ascochyta leaf and pod spot of the pea is discussed. Ascochyta blight is separated into three diseases and the following terminology is proposed: Ascochyta leaf and pod spot (*Ascochyta pisi* Lib.), Mycosphaerella blight (*Mycosphaerella pinodes* (Berk. and Blox.) Stone), and Ascochyta footrot (*Ascochyta pinodella* n. sp.). The nature of the three diseases and of the three causal organisms is discussed and the new species is described. Color plates are used to distinguish the cultural characteristics of the organisms and the host symptoms of the diseases. Observations on life history of the organisms in relation to disease are given. Mycosphaerella blight is considered the most damaging of the three diseases.

Laboratory tests of a large number of pea seed samples from the harvests of 1924, 1925, and 1926 were made. The results show that seed produced in the semi-arid seed-growing areas of the western United States was practically always free from fungous infection, while a large percentage of the seed produced in eastern North America was more or less infected with *Ascochyta* spp. and other fungi.

The results of greenhouse and field tests with healthy and diseased seed show, in general, a decreased percentage stand of plants from diseased seed as compared with that from healthy seed. The treatment of seed with organic mercury dusts was more or less beneficial in increasing the percentage stand of plants. This benefit was greater when the percentage of seed infected per sample was high and when the seed was planted under soil conditions adverse to rapid germination. The treatment of diseased seed was of value in reducing the amount of footrot injury caused by *M. pinodes* and *A. pinodella*, but showed no benefical results in controlling the spread of *A. pisi* from infected seed to the above-ground parts of the plant.

Many inoculation trials were made with the three organisms on canning, market garden, and field varieties of peas, in an attempt to find immune or resistant varieties. The results of these inoculations showed that some varieties were much more susceptible to injury than others.

HISTORICAL

An organism associated with the disease commonly known as Ascochyta blight of the pea was first described as *Ascochyta pisi* by Madame Libert (1830).[1] The disease, however, had been noted centuries before according to Comes (1879), who wrote,[2] "This disease, studied especially on chickpea, was known even by Theophrastus and Pliny, and was noted by Re under the name of 'rabbia' of chickpea."

Further descriptions were made by Link (1833) and Berkeley (1841, 1860). Ascochyta blight as a serious economic factor in the growing of peas appears in literature in the writings of Halstead (1894), Krüger (1895), van Hook (1906), and others. The description of *A. pisi* given by Saccardo (1884) agrees with that given by Libert (1830) and is regarded as the typical description of the species. (See Plate IV.)

Stone (1912) and Vaughan (1913) considered *Mycosphaerella pinodes* (Berk. and Blox.) Stone to be the ascigerous stage of *A. pisi*. The writer (1927) has pointed out that the disease caused by *M. pinodes* differs markedly from that caused by *A. pisi*, and that these two organisms have been confused in the literature. (See Plates IV and V.) This is substantiated by the recent publication by Linford and Sprague (1927) in which technical descriptions are given to separate *M. pinodes* and "*Mycosphaerella pinodes*, micro form?" from *A. pisi*.[3]

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[1]Refers to Literature Cited, page 45.

[2]Free translation.

[3]Since the pycnidial (Ascochyta) form of *Mycosphaerella pinodes* has never received a specific name, it appears advisable, in order to avoid confusion, to name it and describe it as follows:

Ascochyta pinodes (Berk. and Blox.) n. comb. Spots on leaves and pods, irregular to circular, not definitely margined, sometimes zonate, dark brown, sometimes lighter when zonate, 0.5 to 7.0 mm; on stems and upper taproots, spots small to extensive, purplish-brown to dark brown, pronounced at nodes; pycnidia scattered, indistinct, irregularly depressed globose, ostiolate, light to dark brown, 65 to 180μ; spores hyaline, oblong, ends rounded, straight or somewhat curved, 1–(1–3) septate, more or less constricted at septum, 10 to 21 x 2.7 to 6.1μ.

On leaves, stems, pods, and seeds of *Pisum sativum* L.

NATURE OF THE DISEASES

The disease caused by *M. pinodes* is characterized by brown to purplish, irregular, not definitely margined areas on foliage. Sometimes, in the presence of moisture for prolonged periods the lesions become larger, circular, and somewhat zonate. The small, brown to purplish irregular dots which appear on the pods may enlarge to irregular purplish areas, or large areas may become blotched with the coalescing of the irregular, brown to purplish lesions. Early symptoms of the disease on the stems are noted as black to purplish streaks, more pronounced at the nodes, which may enlarge into brown to purplish irregular areas on the entire stem for 6 to 10 inches above the roots (Plate V). Lesions are often not defined on mature plant parts, especially on the more susceptible varieties such as Green Admiral. In such cases the pods have a gray, pitted appearance and the leaves become shriveled with the appearance of freshly cured hay.

The symptoms manifested by the host when attacked by the micro form organism are strikingly similar to those described for *M. pinodes*. The only marked differences are that the foliage lesions are seldom abundant and almost always develop into more nearly regular, somewhat circular, zonate lesions (Plate V, A).

The symptoms of the disease caused by *A. pisi* are definite, sunken, tan to brown spots, circular on leaves and pods and elongate on stems and petioles. A dark brown margin, often prominent, usually surrounds the tan spot (Plate IV). In contrast with the symptoms caused by *M. pinodes* and by the micro form, stem lesions are seldom abundant and have never been noted to extend below the surface of the ground.

NATURE OF THE ORGANISMS

Cultural studies have revealed marked differences among the three organisms, as is shown in Table 1.[4]

Comparisons of the organisms were made on oat agar, potato agar, yeast agar, sweet clover stems, and pea stems. The differences among the three organisms were shown best on oat agar, pea agar, and yeast agar, and the least difference was noted on potato agar. The difference in growth between *A. pisi* and *M. pinodes* is best shown by transferring several loops of a spore suspension (four or

[4]The writer is indebted to Dr. F. R. Jones of the University of Wisconsin for the culture of "*M. pinodes*, micro form?" which was studied in comparison with other isolations.

five spores per high power field) of the organism in water to freshly prepared test tube slants of oat agar and allowing the cultures to incubate for 8 to 12 days at 18° C. Under these conditions little mycelial growth is made on the agar, but most of the agar slant is covered with pycnidia (Plate I). The exudate of carrot red[5] spore masses from the *A. pisi* pycnidia often covers the entire slant surface in the tubes, while the light buff to flesh spore mass exudate from the black *M. pinodes* or micro form pycnidia is relatively scarce.

TABLE 1.—COMPARISON OF THE GROWTH ON OAT AGAR AT 18° C PRODUCED BY THE THREE ASCOCHYTA ORGANISMS CAPABLE OF CAUSING A DISEASED CONDITION OF PEA PLANTS.

ORGANISM	DISCOLORATION OF AGAR	COLOR OF PYCNIDIA	SPORE EXUDATE FROM PYCNIDIA		ASCIGEROUS STAGE PRODUCED
			Abundance	Color	
M. pinodes	Not discolored	Black	Slight	Light buff to flesh	Yes
A. pisi	Straw colored near surface	Tan to brown	Abundant	Carrot red	No
"*M. pinodes*, micro form?"	Brown to black	Black	Slight	Light buff	No

Pycnospores of *M. pinodes* usually contain numerous scattered oil globules, while those of *A. pisi* may have one conspicuous oil globule near each end of the spore with the remainder of the protoplast of a smooth, homogeneous nature.

Cultures of *A. pisi* isolated from pea seed grown in New York, eastern Canada, Michigan, Wisconsin, Minnesota, and England have been studied comparatively. No marked variations in cultural characteristics or spore measurements have been noted. Comparative studies of cultures of *M. pinodes* from pea seed grown in New York, eastern Canada, and Wisconsin have shown them to be similar in type of growth, spore production, and spore measurements. The micro form organism has been isolated from pea seed grown in New York, eastern Canada, Michigan, Wisconsin, Montana, and Idaho. Comparative studies of these micro form isolations and a culture obtained from the University of Wisconsin show the cultures to be similar.

Pycnospore measurements for the three organisms are given in Table 2. The measurements of pycnospores of *A. pisi* and of *M. pinodes* differ from those reported by Linford and Sprague (1927)

[5]Color of spore masses given according to "Color Standards and Nomenclature," R. Ridgway, Washington, D. C. 1912.

TABLE 2.—COMPARATIVE PYCNOSPORE MEASUREMENTS OF THE THREE ASCOCHYTA ORGANISMS CAPABLE OF CAUSING A DISEASED CONDITION OF PEA PLANTS.*

SOURCE OF SPORES†	*Ascochyta pisi*		*Mycosphaerella pinodes*		"*M. pinodes*, MICRO FORM?"	
	Limits	Average	Limits	Average	Limits	Average
	Microns	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*
Oat agar	2.7–3.6 x 13.5–14.4	3.5 x 14.0	3.6–4.5 x 10.8–18.0	3.8 x 14.4	2.2–2.7 x 4.5–7.2	2.3 x 5.4
Oat agar	2.7–3.6 x 12.6–16.2	3.0 x 14.4	3.6–4.5 x 10.8–14.4	3.6 x 14.1	2.2–3.1 x 4.5–8.1	2.4 x 5.3
Oat agar	2.7–3.6 x 12.6–16.2	2.7 x 14.5	4.5–5.4 x 12.6–14.4	5.2 x 14.1	2.7–3.6 x 4.5–9.0	3.1 x 6.3
Oat agar	2.7–3.6 x 14.4–16.2	2.9 x 14.8	3.6–5.4 x 12.6–18.0	4.1 x 15.2	2.2–3.1 x 4.5–8.1	2.7 x 5.7
Oat agar	3.6–5.4 x 10.8–16.3	3.4 x 13.1	3.6–4.5 x 7.2–14.5	3.7 x 14.2	2.4–3.4 x 4.2–8.5	2.5 x 6.0
	Average	**3.2 x 14.2**		**4.1 x 14.4**		**2.6 x 5.7**
Water agar	3.6–4.5 x 9.0–14.4	3.7 x 12.7	3.6–4.5 x 11.7–15.3	3.7 x 13.8	1.8–4.5 x 4.5–10.8	3.2 x 7.7
Water agar	3.4–4.2 x 10.6–15.1	3.7 x 13.8	4.0–4.8 x 12.2–14.6	4.2 x 14.2	2.2–3.6 x 4.6– 9.0	2.8 x 7.5
	Average	**3.7 x 13.2**		**4.0 x 14.0**		**3.0 x 7.6**
Leaf lesions	3.2–5.8 x 12.4–18.6	4.4 x 15.1	3.6–5.4 x 10.8–14.4	4.2 x 12.8	1.8–3.6 x 5.4–10.8	2.8 x 7.6
Leaf lesions	3.6–4.5 x 12.6–16.2	3.8 x 14.3	3.5–6.1 x 13.1–18.4	4.6 x 15.2	1.5–3.4 x 6.1–12.2	2.4 x 8.1
Leaf lesions	3.8–5.6 x 12.1–14.8	4.1 x 14.4	4.5–5.4 x 10.8–16.2	4.8 x 12.1	1.9–3.6 x 5.2–10.4	2.6 x 7.9
Leaf lesions	3.2–5.4 x 10.9–15.1	4.6 x 14.2	3.7–5.5 x 10.9–15.1	4.4 x 14.3	2.7–3.6 x 7.2–10.8	3.5 x 9.0
Leaf lesions	2.7–3.6 x 12.8–14.4	3.4 x 12.6	2.7–3.6 x 12.8–14.4	3.4 x 13.6	2.7–3.6 x 7.2–12.6	3.5 x 9.0
	Average	**4.1 x 14.1**		**4.3 x 13.6**		**2.9 x 8.3**

* Based upon measurements of 100 spores per organism in each series.

†The different series of measurements were made at various times on the three organisms comparatively. Leaf lesions were from controlled inoculated plants in greenhouse and field.

in that the organisms cannot be separated on the basis of mean length of the spores.

In the comparative study of the three organisms the ascigerous stage of *M. pinodes* was found in many of the transfers. This was the case especially when the water suspension of spores was placed on sterile sweet clover stems. The perithecia were always produced in great abundance. In these studies the writer was unable to find an ascigerous stage either in cultures of the micro form or in cultures of *A. pisi*.

Measurements of mature ascospores of *M. pinodes* are given in Table 3. These measurements are slightly greater than those recorded by Stone (1912). Otherwise the morphological characters of the organism described by Stone are similar to those noted for *M. pinodes* by the writer. Mature perithecia have been found on oat agar and on sweet clover stems in 10 to 13 days after spore suspensions had been transferred to the culture tubes. On one occasion a single ascospore isolation of *M. pinodes* produced mature perithecia in abundance on oat agar 28 days after the spore isolation was made.

TABLE 3.—ASCOSPORE MEASUREMENTS OF *M. pinodes*.*

SOURCE OF SPORES	INOCULATION NO.	ASCOSPORE MEASUREMENTS	
		Limits	Average
		Microns	*Microns*
Leaves	67	6.3–8.1 x 15.3–17.1	7.2 x 16.2
Leaves	68	7.2–8.1 x 16.2–18.9	7.4 x 17.5
Oat agar	—	7.2–9.9 x 18.0–19.8	9.0 x 18.9

*Based, in each case, upon the measurements of 100 spores.

The production of perithecia containing mature ascospores has been observed on plants in practically all cases where *M. pinodes* was used as inoculum. Table 4 records information relative to the production of the ascigerous stage on plants inoculated with *M. pinodes*. In these series of inoculations comparative inoculations were made with the micro form and with *A. pisi*, but in no case was the writer able to observe an ascigerous stage on plants inoculated with either of these organisms.

Another marked difference between *A. pisi*, *M. pinodes*, and the micro form was noted in the period of incubation on the host necessary to produce macroscopic lesions. The indefinite, light green, sunken lesions caused by *A. pisi* appear on the leaves in six to eight days after inoculation and become tan with definite brown margins two or three days later. The small purplish-brown spots caused by *M.*

pinodes and by the micro form appear on the foliage in two to four days after inoculation and slowly develop into the typical larger lesions, the rate of development depending upon the prevailing moisture and temperature conditions.

TABLE 4.—THE PRODUCTION OF MATURE PERITHECIA ON PLANTS INOCULATED WITH *M. pinodes*.

VARIETY INOCULATED	INOCULATION NO.	DATE INOCULATED	MATURE PERITHECIA FOUND*		LOCATION OF INOCULATED PLANTS
			Date	Host part	
Advancer	67	Oct. 6, 1926	Nov. 1, 1926	Leaves	Greenhouse
Green Admiral	68	Oct. 27, 1926	Nov. 18, 1926	Leaves	Greenhouse
Alaska	67A	Oct. 21, 1926	Nov. 19, 1926	Leaves	Greenhouse
Alaska	67A	Oct. 21, 1926	Nov. 26, 1926	Stems	Greenhouse
Green Admiral	69A	Nov. 20, 1926	Dec. 3, 1926	Leaves	Greenhouse
Green Admiral	—†	Oct. 22, 1926	Dec. 16, 1926	Stems	Greenhouse
Green Admiral	—†	Nov. 20, 1926	Jan. 10, 1927	Stems	Greenhouse
8 varieties	5	June 15, 1927	July 17, 1927	Leaves	Field
8 varieties	8	June 18, 1927	July 17, 1927	Leaves	Field
8 varieties	8	June 18, 1927	July 17, 1927	Stems	Field
8 varieties	11	June 20, 1927	July 17, 1927	Leaves	Field
8 varieties	14	June 21, 1927	July 17, 1927	Leaves	Field
16 varieties	17	June 23, 1927	July 17, 1927	Leaves	Field
16 varieties	20	June 24, 1927	July 17, 1927	Leaves	Field
16 varieties	23	June 27, 1927	July 17, 1927	Leaves	Field
16 varieties	26	June 28, 1927	July 17, 1927	Leaves	Field
16 varieties	29	July 2, 1927	July 17, 1927	Leaves	Field

*Frequent observations were made after inoculation to ascertain the earliest date at which ascospores were mature.

†Infected seed planted in flats on dates noted as date inoculated. Plants came up but many died and perithecia were produced abundantly on dead stems.

Various isolations of the three organisms have been carried in culture for two years and transferred repeatedly to fresh media, but no change in their distinctive characters has been noted. Numerous single ascospore isolations from cultures and from host parts have been made and the typical *M. pinodes* organism has always developed from the isolation. This has been checked repeatedly by inoculation of host as well as by a study of cultural characters.

From the data and the observations discussed above and summarized here it appears advisable to consider the micro form organism as a new species distinct from *Mycosphaerella pinodes*.

1. Spore measurements differ materially from those of *M. pinodes*.

2. An ascigerous stage has not been found in association with the micro form organism.

3. Inoculation trials and reisolations have demonstrated the stability of the organism.

4. Cultural characteristics of the two organisms are different and the organisms have remained distinct after repeated transfers.

The new species of Ascochyta is described as follows:

Ascochyta pinodella n. sp. Spots on leaves and pods, irregular to circular, not definitely margined, sometimes zonate, dark brown, sometimes lighter when zonate, 0.5 to 8 mm; on stems and upper taproots, spots small to extensive, purplish-brown to dark brown, pronounced at nodes; pycnidia indistinct, scattered, irregularly depressed globose, ostiolate, light to dark brown, 79 to 182μ; spores hyaline, continuous or uniseptate, continuous spores oval to oblong, 5 to 12 x 1.5 to 4.5μ, uniseptate spores oblong, rounded at ends, more or less constricted at septum, 5 to 13 x 2.0 to 4.5μ. Parasitic on *Pisum sativum* L. in New York and in seed of *P. sativum* from New York, eastern Canada, Michigan, Wisconsin, Montana, and Idaho.

It is proposed that the terms Ascochyta leaf and pod spot, Mycosphaerella blight, and Ascochyta footrot be used in designating the diseases caused by *Ascochyta pisi*, *Mycosphaerella pinodes*, and *Ascochyta pinodella*, respectively.

ECONOMIC IMPORTANCE

Serious losses in pea crops caused by species of Ascochyta have been reported in the literature in several cases. As early as 1879 Comes reports the disease as affecting the pea stems so seriously as to cause a wilting of the tops. Krüger (1895) reports a complete failure of the pea crop in one section of Europe due to an Ascochyta blight that was a virulent footrot disease and turned the vines black. Van Hook (1906) reports that the extent of the crop injured in 1905 in Ohio by Ascochyta blight was 52 per cent. Jones (1911) attributes to Ascochyta blight an important rôle in injury noted on pea plants in Wisconsin in 1911. It appears from a study of the literature that most of the damaging outbreaks of the disease have been caused by *M. pinodes*.

During the season of 1925 extreme damage to the pea crop in New York was noted as having been caused by *M. pinodes*. This loss was not measured by the reduction in yield alone, but by a reduction in the quality of the canned product. If severe outbreaks of the disease occur at or near harvest time, it is extremely difficult

to harvest the crop without having hard peas in the canned product, which greatly reduce its quality.

LIFE HISTORY IN RELATION TO DISEASE

Stone (1912) records data proving that the ascospore stage of *M. pinodes* lives over winter on the old pea stems. From observations by the writer and by Linford and Sprague (1927) it appears that *A. pinodella* can live for at least two years in the soil.

During the winter of 1926–27 the writer exposed pea stems that had been inoculated with *A. pisi* to outdoor weather conditions. Viable pycnospores of *A. pisi* were found on these stems June 2, 1927. This would tend to prove that *A. pisi* may live over the winter on infected pea stems.

From the work of Halstead (1894), Krüger (1895), and van Hook (1906) it has been known that organisms capable of causing the disease known as Ascochyta blight were carried in pea seed. The tests of pea seed by the writer (page 14) have shown that the three organisms may be, and often are, carried in pea seed.

Seed infected with any of these three organisms usually gives a lower germination and a lower stand of plants in the field than does healthy seed. This is especially noticeable when a high percentage of the seed is infected and when the seed is planted under conditions adverse to rapid germination, such as low temperature and high moisture content of the soil.

Seeds infected with *M. pinodes* or *A. pinodella* may produce plants, many of which die after attaining a height of 2 to 6 inches (Fig. 1). The spore-producing bodies of the organisms are produced on the old dead parts above ground, a position very favorable for the spread of the disease to the young growing plants in the field. In the case of *M. pinodes* the ascospore stage, as well as the pycnospore stage, may be produced on these dead plants during the growing season (Table 4, ascospores produced in 51 and 55 days from planting of seed). The ascospores, which are ejected into the air, may be carried long distances and disseminate the disease.

Plants produced from seed infected with *A. pisi* seldom die after emerging from the ground, as do plants from seed infected with the other two organisms. It is common, however, to find typical disease lesions on the first leaves that unfold, the infection having taken place as the seed germinated. The pycnospores produced by the three organisms are not disseminated freely for long distances.

Water splashing, and possibly insect dissemination, appears to be the mode of spread of the disease to nearby plants by pycnospores. This was shown markedly in the out-door series of plat inoculations carried on during the summer of 1927. The individual plats inoculated with the various organisms were 5 feet apart. The first inoculations were made on June 15. Until July 17, when the ascospores

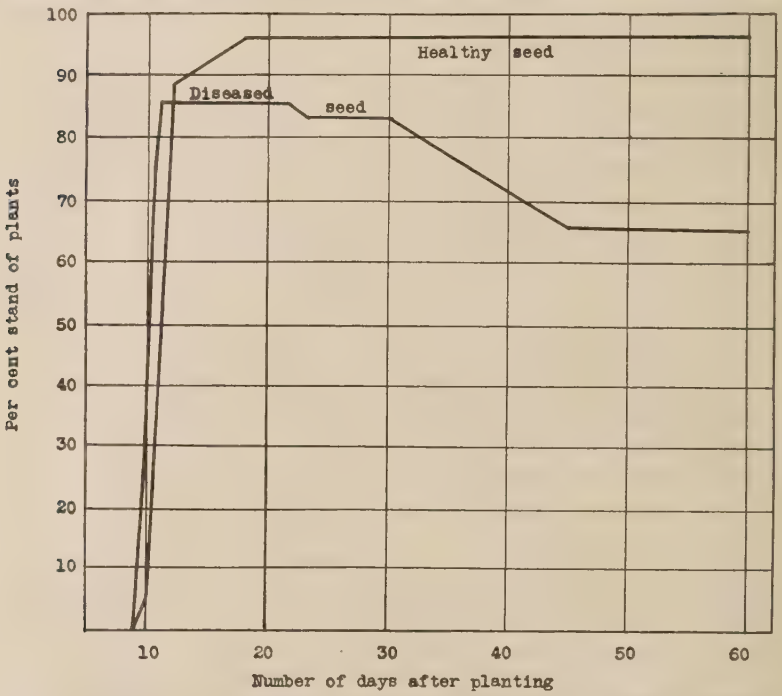

FIG. 1.—STAND OF PLANTS PRODUCED FROM HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED.

Many plants from seed infected with *M. pinodes* or *A. pinodella* emerged from the soil and later died. The fruit bodies of the organisms (including perithecia of *M. pinodes*) were produced on these dead plants before the blossoming of the living plants. (Tests 11 and 12, Table 9.)

were produced on plants inoculated with *M. pinodes*, no spread of any of the organisms outside of their individual plats was noted. After the ascospores were produced *M. pinodes* infection became abundant on all the plats, including uninoculated control plats.

The development of the diseases on the above-ground parts of the plant is dependent upon periods of high humidity during the growing season. In seasons having abundant, prolonged, and timely rains

extreme injury may follow the establishment of the diseases in pea plantings. However, in other seasons little or no damage may be noted.

The use of seed a part of which is infected with *M. pinodes* or *A. pinodella* often leads to the serious footrot described by Gilchrist (1926). *A. pisi*, however, has never been observed to produce this footrot type of lesion.

Pycnidia and spores in abundance are produced in *A. pisi* lesions, and they are usually clustered near the center of the tan spot. Pycnidia on areas of the pea plant infected by *M. pinodes* or *A. pinodella* are scattered and relatively scarce. Comparative inoculations with *M. pinodes* and *A. pinodella* have shown that *A. pinodella* is the less pathogenic on the above-ground parts and the lesions produced are relatively few. In practically every inoculation with ascospores or pycnospores of *M. pinodes* the ascigerous stage has been produced on some of the inoculated parts. The minimum time noted from inoculation to production of mature ascospores on leaves was 13 days. The production of mature perithecia on inoculated plant parts appears to be closely correlated with the presence of considerable moisture. Short periods for ascospore production have been noted in cases where inoculated leaves were in contact with moist soil. Also, in the large outdoor series of inoculations the dry weather of early July inhibited perithecial formation and all of the plats showed an abundance of mature perithecia on July 17 following a prolonged rainy period. It will be noted in Table 4 that some of these plats were inoculated on June 15, while the last inoculations were made on July 2. This correlation of moisture with the production of mature perithecia of *M. pinodes* can be directly associated with the damaging outbreak of the disease in New York in 1925. In several of the districts where the disease was most serious, seed tests showed that diseased seed[6] had been used, assisting in the early establishment of *M. pinodes* on the pea plants in those districts. From one to two weeks prior to the harvesting of most late varieties prolonged rains occurred allowing for the production and rapid dissemination of the disease over entire districts. Mature perithecia were found in abundance on Green Admiral plants during the early part of the blossoming period. In 1926 it was fairly dry during and preceding the harvest period and the disease was of little importance.

[6]The term "diseased seed" as used in this publication refers to a lot of seed, a part of which was infected with *M. pinodes*, *A. pisi*, or *A. pinodella*.

During the season of 1927 there were prolonged rainy periods near the end of the harvest period and considerable spread of the disease was noted in a few canning areas, but it occurred too late to cause much damage to the crop. Plants of the Rogers Winner variety sent in from another state in 1927 showed an abundance of mature perithecia one week before they were harvested for canning.

STUDIES OF CONTROL MEASURES

The nature of the diseases and a knowledge of the Ascochyta organisms capable of causing damage to pea plants have led to a study of various methods of limiting or controlling the diseases. The methods that may be adaptable as control measures can be listed as follows: The use of healthy seed, treatment of seed, development of resistant varieties, application of fungicides to the growing plants, crop rotation, and destruction of pea refuse. Studies of some of these means of control have been initiated.

SOURCE OF HEALTHY SEED

In order to standardize a method of testing for the presence of organisms carried in pea seed various sterilizing materials were used comparatively as disinfectants of the seed coats. Mercuric chloride, formalin, Uspulun, and calcium hypochlorite were used. The calcium hypochlorite solution recommended by Wilson (1915) gave excellent results as a sterilizer of the seed coats and did not inhibit or decrease the growth of the fungus from the interior of the seed. The following method was used to determine the disease content of seed samples.

Ten grams of calcium hypochlorite were placed in 140 cc of distilled water. After 15 minutes, during which the mixture was stirred frequently, it was filtered. The 50 seeds from each sample to be tested were placed in a volume of the filtrate at least five times as great as the volume of the seeds. The seeds were allowed to soak in the sterilizing solution for 4½ hours with frequent stirring to dislodge air bubbles from the seed coats. The seeds were then removed to sterile flasks or tubes containing a small amount of oat agar. The oat agar was made as follows: Fifty grams of rolled oats in 500 cc of water were heated over a free flame until cooked, allowed to stand for 1 hour, filtered thru cheesecloth, and the filtrate made up to 500 cc volume with water. Fifteen grams of agar were dissolved in 500 cc of water and added to the oat filtrate. Preliminary tests were made by using about 10 cc of the medium in large test tubes,

placing one seed in each test tube. Later tests were made in 500-cc flasks containing about 30 cc of the medium, 50 seeds being placed in each flask. A wire mesh screen shaped as a scoop was kept in a beaker of calcium hypochlorite solution. The seeds could be poured with the sterilizing solution from the beaker to the screen and then poured directly into the sterile flasks containing congealed agar. Daily observations of the seeds were made and any fungous growth was noted (Plate II). After 7 to 10 days microscopic examinations and tranfers to tubes were made to determine the identity of any organisms present. Whenever species of Ascochyta were present pycnidia containing mature spores could be found.

Forty-one samples of pea seed harvested in 1924 were tested and the results of the tests are recorded in Table 5. The one sample from Michigan contained 12 per cent of the seed infected with *A. pisi* and 4 per cent infected with *M. pinodes*. The 10 samples grown in New York showed varying percentages of the three organisms and in several cases two or all three organisms were present in the same lot of seed. *A. pisi* was present in 80 per cent of the samples, *M. pinodes* in 40 per cent, and *A. pinodella* in 10 per cent.

TABLE 5.—RESULTS OF TESTS TO DETERMINE THE PRESENCE OF SPECIES OF ASCOCHYTA IN PEA SEED HARVESTED IN 1924.

WHERE GROWN	NUMBER OF SAMPLES TESTED	NUMBER OF SAMPLES DISEASED*	AVERAGE PERCENTAGE OF INFECTED SEED IN DISEASED SAMPLES
California	1	0	——
Idaho	18	0	——
Michigan	1	1	16
Montana	4	0	——
New York	10	10	15
Washington	7	0	——

*Seed more or less infected with *Ascochyta* spp.

Similar tests were made on 828 samples of seed harvested in 1925 and the results are listed in Table 6. The samples came from various seed-growing areas in the states listed. A study of the distribution of these areas shows that practically all of the larger seed-growing areas are represented. The samples of seed from Montana and Idaho showing a trace of infection carried *A. pinodella* only. The tests of diseased seed again showed a predominance of *A. pisi*, varying with the locality where the seed was grown. About 65 per cent of the samples contained *A. pisi;* 45 per cent, *M. pinodes;* and 5 per cent, *A. pinodella.* In many tests of diseased seed other organisms were

present which, in a few cases, made it impossible to determine definitely the presence of *Ascochyta* spp. The following organisms other than *Ascochyta* spp. were found to be carried in pea seed: *Alternaria* sp., *Cephalothecium* sp., *Fusarium* spp., *Penicillium* sp., *Actinomyces* sp., *Rhizoctonia* sp., and bacteria. These organisms were rarely found in tests of seed from the areas where Ascochyta-free seed was produced.

TABLE 6.—RESULTS OF TESTS TO DETERMINE THE PRESENCE OF SPECIES OF ASCOCHYTA IN PEA SEED HARVESTED IN 1925.

WHERE GROWN	NUMBER OF SAMPLES TESTED	NUMBER OF SAMPLES DISEASED*	AVERAGE PERCENTAGE OF INFECTED SEED IN DISEASED SAMPLES
California	46	0	——
Eastern Canada	38	33	6
Idaho	250	5	trace
Michigan	209	139	8
Minnesota	11	9	5
Montana	103	1	trace
North Dakota	1	0	——
New York	45	45	14
Washington	61	0	——
Wisconsin	51	47	8
Wyoming	13	0	——

*Seed more or less infected with *Ascochyta* spp.

The tests of pea seed harvested in 1926 included 693 samples from districts well distributed over the pea seed growing areas. Results of these tests are recorded in Table 7.

TABLE 7.—RESULTS OF TESTS TO DETERMINE THE PRESENCE OF SPECIES OF ASCOCHYTA IN PEA SEED HARVESTED IN 1926.

WHERE GROWN	NUMBER OF SAMPLES TESTED	NUMBER OF SAMPLES DISEASED*	AVERAGE PERCENTAGE OF INFECTED SEED IN DISEASED SAMPLES
California	11	0	0
Eastern Canada	56	47	15
Western Canada	3	0	0
England	18	17	23
Idaho	235	0	0
Michigan	63	51	12
Montana	87	3	trace
New York	36	35	13
Washington	24	0	0
Wisconsin	155	78	10
Wyoming	5	0	0

*Seed more or less infected with *Ascochyta* spp.

The 17 samples of diseased seed from England contained only the *A. pisi* organism. Most of the seed from eastern Canada was produced in Ontario. Ninety-six per cent of the diseased samples harbored *A. pisi* and 11 per cent *M. pinodes*. The samples of seed from New York, Michigan, and Wisconsin were infected mostly with *A. pisi*, while about 20 per cent of the samples carried *M. pinodes*, and 1 per cent *A. pinodella*. The three samples of seed from Montana having less than 1 per cent of the seed infected carried *A. pinodella*.

A study of Tables 5, 6, and 7 shows that the seed produced in the semi-arid western seed-growing areas during 1924, 1925, and 1926 was practically free from *Ascochyta* spp. Also, that seed produced in the eastern United States and eastern Canada, where conditions are more favorable for disease development on the growing plants, was, in a high percentage of cases, more or less diseased.

The entrance of *Ascochyta* spp. into the pea seed appears to be largely dependent upon periods of rainfall after the pods are formed and before harvest. The fungi attack the pods and penetrate into the pea seed. Observations by the writer have shown that fields may appear to be relatively free from injury from *Ascochyta* spp. at the time of harvest for canning, but with prolonged periods of rain prior to seed harvest heavy infection of the seed may take place. This was noted especially when adverse weather delayed the harvest of seed after it was mature. The different species of Ascochyta are able to penetrate the mature pods very freely and enter the seed. It appears that the other organisms that have been found in pea seed (page 16) primarily gain entrance to the seed under adverse weather conditions at or near harvest time or thru Ascochyta lesions. Under conditions of dry farming or irrigation farming found in the western part of the United States there is usually not sufficient rain to spread the disease in the pea fields. It is reasonable to expect that seed practically free from these organisms will always be produced under such conditions. The tests recorded in Tables 5, 6, and 7 were made on seed of varieties used in the canning industry, with the exception of the 18 samples from England (Table 7) which were varieties used in the market garden trade.

Practically all of the commercial canning varieties have been used in these tests. The early varieties, such as Alaska and Surprise, have usually shown a lower percentage of samples carrying *Ascochyta* spp. than the late varieties. This appears to be due largely to earlier harvesting of these varieties and, consequently, less exposure to field

conditions favorable for disease spread (Table 8). The Green Admiral variety has usually carried a larger percentage of disease than Horsford or Perfection. This is probably correlated with the high degree of susceptibility of this variety to attack and injury by the Ascochyta organisms, as shown in resistance studies (Table 19). Tests of a large number of field pea varieties during 1927 have given results similar to those obtained with canning varieties relative to areas producing Ascochyta-free seed.

TABLE 8.—THE PREVALENCE OF *Ascochyta* SPP. IN FOUR VARIETIES OF PEAS HARVESTED IN VARIOUS SEED GROWING AREAS IN 1925.*

WHERE GROWN	ALASKA			ADMIRAL			HORSFORD			PERFECTION		
	Total number samples	Percentage samples diseased	Average percentage infected	Total number samples	Percentage samples diseased	Average percentage infected	Total number samples	Percentage samples diseased	Average percentage infected	Total number samples	Percentage samples diseased	Average percentage infected
New York	15	100	9	18	100	17	3	100	12	—	—	—
Eastern Canada	11	73	5	1	100	12	10	90	6	—	—	—
Michigan	97	36	4	47	98	11	17	100	8	34	85	10
Wisconsin	11	91	7	6	100	9	11	100	6	2	100	10

*A detailed summary of part of Table 6.

Laboratory germination tests according to the official seed analysts' methods[7] were made on almost all of the seed samples. The results of these tests showed that the percentage of viable seed, expressed in percentage of germination, was, in general, of no value as an indicator of fungous infection in the seed (Tables 13 and 18). It is possible to determine the presence of these organisms in pea seed in germination tests, altho not as accurately as in tests with an agar substratum under sterile conditions. Seed that is infected with fungous organisms usually shows the fungous growth coming from the seed in three to seven days in the incubator. In microscopic examination of the fungous growth *Ascochyta* spp. may be identified by the presence of the fruit bodies. In tests made by the writer the presence of fungous organisms coming from within germinating pea seed in the seed analysts' tests was almost always a reliable indication that *Ascochyta* spp. were present in some of the fungus-in-

[7]One hundred seeds were spaced on wet absorbent paper and rolled into a "doll." The "doll" was placed in a moist incubator for 5 days and the number of seeds with extended hypocotyl was expressed as the percentage of germination.

fected seeds. In the tests of over 1,500 samples of pea seed from three years' harvest only 10 samples of seed carried fungous organisms when *Ascochyta* spp. were not present. Seed produced in the more arid regions of the United States was rarely infected with any fungous organism.

Seed analysts' reports would be more valuable to pea growers if they included a statement of the percentage of seed infected with fungous organisms and especially with *Ascochyta* spp.

TESTS OF DISEASED AND HEALTHY SEED IN SOIL

In order to obtain data on the comparative stand of plants produced from diseased and from healthy seed, and on the effect of seed treatment, tests were conducted in the greenhouse and in the field.

GREENHOUSE EXPERIMENTS, 1925–1926

Preliminary experiments in the greenhouse in 1925 showed the necessity of planting the seeds uniformly spaced at a uniform depth with uniform moisture content of the soil if comparable results were to be obtained. In the greenhouse tests during the winter of 1925–26, the following method of planting was used: The seeds were planted in four rows 3 inches apart in flats 15 x 21 x 4 inches. The 50 seeds in each flat were placed 1½ inches apart in the rows and uniformly covered with 1 inch of soil. The soil, with a moisture content of about 60 per cent of its moisture-holding capacity, was thoroly mixed before it was placed in the flats. To aid in uniformity of results no water was added to the soil after planting until the plants began to emerge from the soil. The soil was then watered frequently to maintain favorable growing conditions but drenching was avoided. Records of the plants emerging were made every two or three days until the maximum number appeared. Frequent observations and records were made of the condition of the plants until they were removed from the soil. The plants were carefully removed from the soil and records were made of their height and of the presence or absence of disease lesions on the lower part of the stem or on the root system. The results of these tests on the Green Admiral variety are recorded in Table 9 and are discussed according to the related problems involved. The tests recorded in Table 9 were all made with seed from one lot of healthy seed and one lot of diseased seed. Both lots had a laboratory germination record of 98 per cent.

TABLE 9.—RESULTS OF GREENHOUSE TESTS OF TREATMENT OF HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED, GENEVA, N. Y., 1925.

NATURE OF TEST	TEST No.*	BEFORE PLANTING		WHEN PLANTS WERE REMOVED FROM SOIL		
		Seed infected†	Laboratory germination	Stand of plants	Plants with footrot lesions	Average height of plants
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Inches*
Control	1	28	98	70	100	20
Planted in steamed soil	2	28	98	64	100	15
Semesan treatment	3	28	98	96	12	23
Uspulun treatment	4	28	98	94	13	17
Mercuric chloride treatment	5	28	98	76	27	20
Sulfur treatment	6	28	98	84	35	21
Calcium hypochlorite treatment	7	28	98	48	35	23
Small (11 per cent) seed	8	54	90	78	100	19
Medium (53 per cent) seed	9	20	98	84	100	21
Large (36 per cent) seed	10	11	100	92	100	23
Control	11	0	98	96	4	24
Control	12	28	98	66	100	22
Semesan treatment	13	0	98	98	0	20
Semesan treatment	14	28	98	88	5	21
Uspulun treatment	15	0	98	92	2	23
Uspulun treatment	16	28	98	88	30	22
Copper carbonate treatment	17	0	98	90	2	19
Copper carbonate treatment	18	28	98	70	100	18
Jabonite treatment	19	0	98	94	14	16
Jabonite treatment	20	28	98	60	100	14
Sulfur treatment(wet)	21	0	98	96	0	21
Sulfur treatment(wet)	22	28	98	72	100	19
Sulfur treatment (dry)	23	0	98	96	2	21
Sulfur treatment (dry)	24	28	98	82	92	21
Small (11 per cent) seed	25	0	98	88	4	21
Semesan treatment, small seed	26	0	98	94	0	20
Small (11 per cent) seed	27	54	90	74	100	18
Semesan treatment, small seed	28	54	90	90	0	22
Large (89 per cent) seed	29	0	98	96	0	23
Large (89 per cent) seed	03	18	98	82	100	23

*Tests Nos. 1 to 10 planted Oct. 21, 1925; removed from soil Jan. 8, 1926. Tests Nos. 11 to 30 planted Dec. 15, 1925; removed from soil Feb. 21, 1926.

†Seed from the same healthy and diseased lots used in all tests. Diseased seed carried the following organisms: *Altenaria* sp., 10 per cent; *A. pisi*, 8 per cent; *M. pinodes*, 4 per cent; *A. pinodella*, 4 per cent; and *Fusarium* sp., 2 per cent.

Steamed soil.—The soil used in test 2 was placed in shallow boxes with cheesecloth bottoms and autoclaved for 3 hours at 20 pounds pressure.

Treatment of seed.—The organic mercury dusts, Jabonite, and copper carbonate were used at the rate of 3 ounces to 1 bushel of seed. The seed to be treated was placed in a 250-cc beaker with the dust and shaken for 5 minutes.

Uspulun.—The seeds were presoaked in water for 30 minutes and then soaked in a 0.25 per cent solution of Uspulun for 30 minutes at 90° F. The seeds were washed in water and allowed to dry before planting.

Mercuric chloride.—The seeds were presoaked in water for 30 minutes and then soaked in mercuric chloride solution (1–1000) for 15 minutes. The seeds were washed in water and allowed to dry before planting.

Sulfur.—The seeds were dusted as with the organic mercury dusts (tests 23, 24). In tests 21 and 22 the seeds were immersed in water prior to dusting. Test 6 was made by working sulfur into the soil prior to planting, the sulfur being used at the rate of 1 ton to the acre.

Sizing seed.—The seed was graded thru sieves into the following sizes:

Size (in diameter)	Percentage of sample
Above 18/64 inches	36
16/64 to 18/64 inches	53
Below 16/64 inches	11

The stand of plants obtained from the use of healthy seed was 34 per cent greater than that obtained from the use of the diseased sample of seed. Fig. 1 shows that 85 per cent of the seed in the diseased sample produced plants but that only 66 per cent produced plants that lived until blossoming time. In the test from diseased seed all of the plants alive at blossoming time had more or less serious footrot lesions from which *M. pinodes* and *A. pinodella* were isolated. Only 4 per cent of the plants from healthy seed showed disease lesions on the lower stem. From these lesions *Pythium* sp., *Fusarium martii* var. *pisi*, and *Aphanomyces* sp. were isolated. Plants from diseased seed planted in steamed soil showed footrot lesions when removed from the soil. Microscopic examination of these lesions showed the presence of *M. pinodes* and *A. pinodella* in practically

every stem. There was greater uniformity in height of plants as well as a greater average height of plants from the lot of healthy seed (Fig. 2). Similar results have been noted in many other comparative tests of healthy and diseased seed.

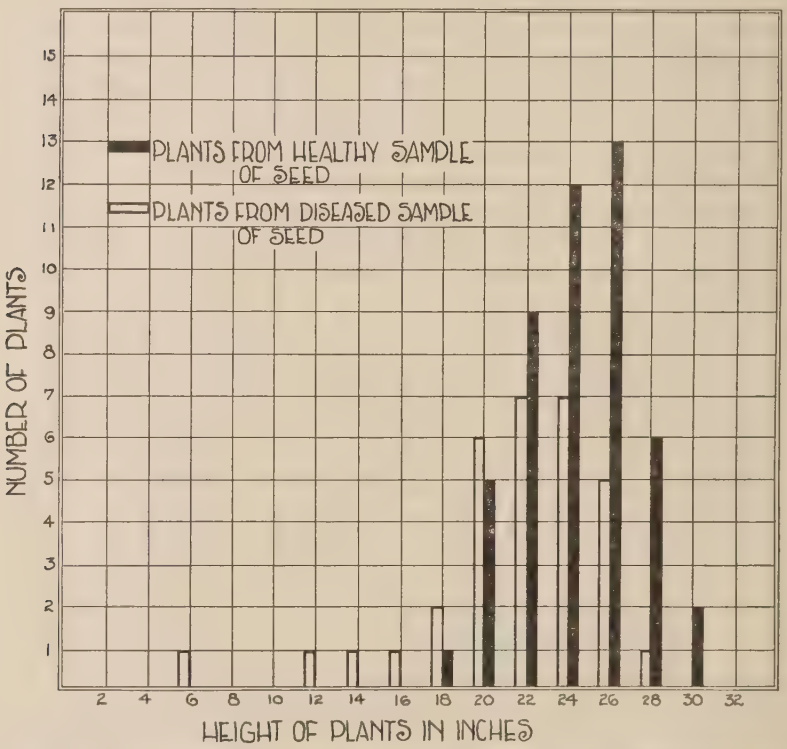

FIG. 2.—COMPARATIVE PERCENTAGE STAND, HEIGHT, AND UNIFORMITY OF PLANTS PRODUCED FROM HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED. (Tests 11 and 12, Table 9.)

Under the favorable temperature (averaging 55° to 60° F) and moisture conditions of the soil in these experiments, no benefit was derived from the treatment of healthy seed. In general, the treatment of diseased seed increased the stand and the uniformity in height of plants as well as reducing the amount of footrot injury. Exceptions were noted in tests 18, 20, 22, and 24 where the two copper compounds and the wet and dry sulfur treatments were of little or no benefit. The two copper compounds markedly reduced the size and

vigor of the plants. Of the materials tested, Semesan dust and the Uspulun treatment gave the greatest increase in stand of plants and each was very effective in checking the development of footrot and basal stem rot caused by *M. pinodes* or *A. pinodella*. These treatments were of no benefit in controlling the development of primary lesions of *A. pisi* on the first unfolding leaves. The treated diseased seed in no case gave as high percentage stand of plants as did the untreated healthy seed. In these and preliminary tests the soaking of pea seed in disinfectant solutions before planting often reduced the percentage germination of the seed in the soil. The liquid disinfectants (Uspulun, formalin, mercuric chloride, and calcium hypochlorite) were no more effective in controlling disease development from infected seed than were the organic mercury dust treatments. For these reasons, the organic mercury dust treatments were used in all further tests.

The grading of seed showed that the larger percentages of infected seeds are in the smaller sized seed, but that the larger seed also may be infected. The grading of healthy seed in these tests was of no value in increasing the stand of plants. The larger sized seed from the diseased lot of seed gave a better stand of plants than did either the smaller seed or an ungraded lot, altho no reduction in footrot injury on living plants was noted.

FIELD EXPERIMENTS, 1926

During the growing season of 1926 field tests were made with healthy and diseased pea seed on the Station's canning crops farm at Geneva.[8]

Healthy and diseased Green Admiral pea seed treated and untreated were tested comparatively in 1/50 acre plats. In treating the seed organic mercury dusts were used at the rate of 2 ounces per bushel of seed. The seed and the dusts were rotated in a drum for five minutes. The diseased seed was from the same lot (having 28 per cent of the seed infected with fungous organisms) as that used in the greenhouse experiments (Table 9). The seed was planted with a farm grain drill at the rate of 3, 4, or 5 bushels per acre. An early (May 6) and a late (May 24) planting was made with each test, and all plats were in triplicate. The counts to determine percentage of stand of plants were made by counting the number of plants in 10 1-yard spaces of 10 rows per plat. Alternate rows were used

[8]Grateful acknowledgment is made to C. B. Sayre of the Division of Horticulture for his cooperation in these experiments.

and 1 yard was skipped between each count yard in diagonal progression across the plat. The results of counts made when the plants were 6 to 8 inches high are recorded in Table 10.

TABLE 10.—RESULTS OF FIELD TESTS OF TREATMENT OF HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED, 1/50 ACRE PLATS, GENEVA, N. Y., 1926.

TREATMENT	PERCENTAGE OF SEED INFECTED	RATE OF PLANTING IN BUSHELS PER ACRE	DATE OF PLANTING	DATE OF RECORD TAKING	AVERAGE PERCENTAGE STAND OF PLANTS WITH STANDARD DEVIATION*
Control	28	4	May 6	June 4	55± 6
Semesan	28	4	May 6	June 4	71± 5
Bayer 101	28	4	May 6	June 4	67± 9
Bayer Sp. II	28	4	May 6	June 4	70± 6
Control	0	4	May 6	June 4	88± 7
Semesan	0	4	May 6	June 4	95± 3
Bayer 101	0	4	May 6	June 4	98± 5
Bayer Sp. II	0	4	May 6	June 4	89±11
Control	0	3	May 6	June 4	84± 5
Semesan	0	3	May 6	June 4	100± 4
Bayer 101	0	3	May 6	June 4	95± 3
Bayer Sp. II	0	3	May 6	June 4	89± 7
Control	0	5	May 6	June 4	92± 4
Semesan	0	5	May 6	June 4	89± 5
Bayer 101	0	5	May 6	June 4	93± 8
Bayer Sp. II	0	5	May 6	June 4	78± 7
Control	28	4	May 24	June 24	61± 2
Semesan	28	4	May 24	June 24	70± 4
Bayer 101	28	4	May 24	June 24	65± 7
Bayer Sp. II	28	4	May 24	June 24	65± 5
Control	0	4	May 24	June 24	80± 3
Semesan	0	4	May 24	June 24	82± 6
Bayer 101	0	4	May 24	June 24	86± 9
Bayer Sp. II	0	4	May 24	June 24	87± 6
Control	0	3	May 24	June 24	88±10
Semesan	0	3	May 24	June 24	98± 1
Bayer 101	0	3	May 24	June 24	100± 3
Bayer Sp. II	0	3	May 24	June 24	86± 4
Control	0	5	May 24	June 24	83± 1
Semesan	0	5	May 24	June 24	92± 2
Bayer 101	0	5	May 24	June 24	96± 9
Bayer Sp. II	0	5	May 24	June 24	85± 1

*Each test was in triplicate, SD = $\sqrt{\frac{\Sigma D^2}{N}}$. Each lot of seed showed a 98 per cent laboratory germination. The healthy and diseased seed were from the same lots as the healthy and diseased seed used in the greenhouse tests (Table 9).

In the 1/50 acre plats the stand of plants from the lot of diseased seed was 15 to 20 per cent less than that from the healthy seed. The treatment of the diseased seed with the organic mercury dusts appeared to increase consistently the stand of plants, the benefit being greater on the early planted seed. Small increases in stand of

PLATE II.—RESULTS OF LABORATORY TESTS TO DETERMINE THE PRESENCE OF SPECIES OF ASCOCHYTA IN PEA SEED.

A. Diseased sample of seed shows white, cottony fungous growth coming from 30 per cent of the seed.

B. Healthy sample of seed shows no fungous growth coming from the seed. (Photographs made six days after the seed coats were sterilized and the seeds placed on oat agar in sterile dishes.)

PLATE III.—THE STAND OF PLANTS PRODUCED FROM THE DISEASED AND HEALTHY SAMPLES OF SEED SHOWN IN PLATE II.

A. Stand of plants from diseased sample of seed.

B. Stand of plants from healthy sample of seed.

(Ten rows of 100 seeds each, planted at uniform depth and distance on May 13, 1927. Photographed July 15, 1927. Green Admiral control plats, Table 17.)

PLATE IV.—ASCOCHYTA LEAF AND POD SPOT OF THE PEA CAUSED BY *Ascochyta pisi*.

PLATE V.—MYCOSPHAERELLA BLIGHT OF THE PEA CAUSED BY *Mycosphaerella pinodes*.
A. FOLIAGE LESIONS CAUSED BY *Ascochyta pinodella*.

PLATE VI. ARRANGEMENT OF PLATS AND THE APPARATUS USED AS MOIST CHAMBERS IN THE VARIETAL INOCULATION EXPERIMENTS REPORTED IN TABLE 19.

PLATE VII.—RESULTS OF COMPARATIVE INOCULATIONS ON (A) HORSFORD MARKET GARDEN AND (B) SURPRISE.

Left, plants inoculated with *A. pisi; center*, plants uninoculated; *right*, plants inoculated with *M. pinodes*. Basal stem-rot was produced by *M. pinodes* but not by *A. pisi*. Surprise showed much greater susceptibility to basal stem injury than did Horsford Market Garden.

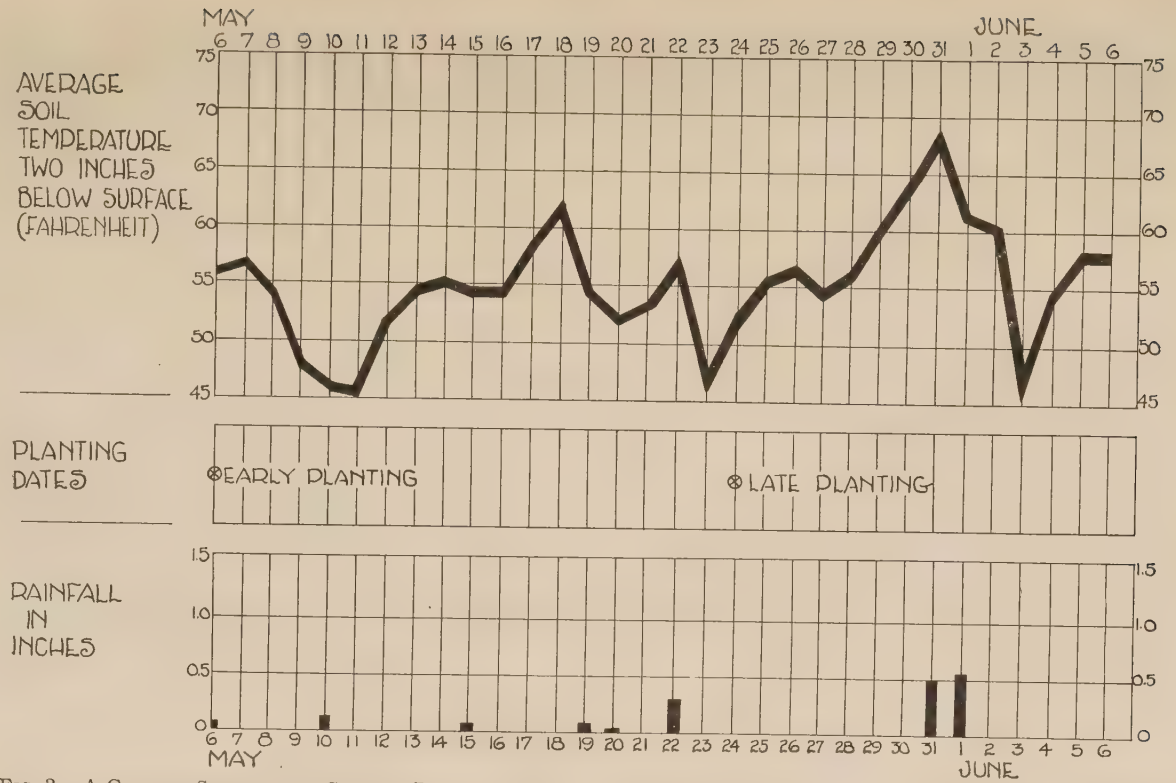

FIG. 3.—A GRAPHIC SUMMARY OF CERTAIN RECORDS RELATING TO RESULTS OF FIELD TESTS OF HEALTHY AND DISEASED PEA SEED, GENEVA, N. Y., 1926.

plants followed the use of organic mercury dusts on the healthy seed. However, the variability of results and the large probable error of the counts do not permit the drawing of conclusions. The temperature and moisture conditions of the soil during and following planting are shown in Fig. 3. Observations and counts made soon after the plants emerged showed that the treatment of seed infected with *A. pisi* did not reduce the number of plants having primary lesions from seed infection.

Further tests of the same lots of healthy and diseased Green Admiral pea seed were made by planting the seeds 1 to 2 inches apart in rows. Samples from the same lots of seed were used at Geneva, Albany, and Yonkers, N. Y. The results of these tests are shown in Table 11.

TABLE 11.—RESULTS OF FIELD ROW TESTS OF DISEASED AND HEALTHY GREEN ADMIRAL PEA SEED AT GENEVA, ALBANY, AND YONKERS, N. Y., 1926.*

TREATMENT	LOCATION OF PLATS	NUMBER OF SEEDS	PERCENTAGE STAND OF PLANTS	
			Healthy seed	Diseased seed
Control	Albany	1,000	86	73
Control	Yonkers	400	86	64
Control	Geneva	200	88	65
Semesan	Geneva	200	90	80
Bayer 110	Geneva	200	91	82
Bayer Sp. II	Geneva	200	86	81

*The same lots of seed were used as in the 1/50 acre plats in 1926 and the greenhouse tests in 1925. The experiments were conducted in cooperation with C. B. Sayre, Geneva, N. Y.; L. D. Kelsey, Albany, N. Y.; and C. R. Orton, Yonkers, N. Y.

In the row tests of these two lots of seed in different localities the lot of healthy seed gave from 13 to 23 per cent greater stand of plants than did the lot of diseased seed. Treatment of the diseased seed with the organic mercury dusts increased the percentage stand of plants, while the treatment of healthy seed with these compounds was of little or no benefit.

A summary of results of comparative tests of the healthy and diseased samples planted in the greenhouse and in the field is shown in Table 12. The percentage stand of plants obtained from the use of healthy seed was much greater than that from diseased seed, altho the two lots of seed showed the same percentage germination in laboratory tests. The diseased seed had the appearance of healthy, normal seed when observed in the bulk. The difference in stand of plants was greater in the field tests than in the greenhouse tests.

TABLE 12.—SUMMARY OF THE PERCENTAGE STAND OF PLANTS PRODUCED FROM THE SAME LOTS OF HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED IN FIELD AND GREENHOUSE EXPERIMENTS, GENEVA, N. Y., 1926.*

TEST NO.	FIELD TESTS				GREENHOUSE TESTS (ROWS IN FLATS)	
	1/50 acre plats†		Sown in rows			
	Healthy seed	Diseased seed	Healthy seed	Diseased seed	Healthy seed	Diseased seed
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	84	60	88	69	100	66
2	76	64	86	62	90	80
3	79	60	82	57	93	75
4	95	62	87	66	85	73
5	78	50	88	65	100	70
6	91	54	86	73	91	62
7	—	—	—	—	98	62
8	—	—	—	—	90	—
9	—	—	—	—	93	—
Average	84	58	86	65	93	70

*28 per cent of seed in the diseased sample was infected with fungous organisms: 8 per cent *A. pisi*; 4 per cent *M. pinodes*; 10 per cent *Alternaari* sp.; 4 per cent *A. pinodella*; and 2 per cent *Fusarium* sp. Each sample germinated 98 per cent in laboratory tests.

†Seed planted at the rate of 4 bushels per acre.

Strain tests of pea varieties conducted on the Station's canning crops farm contained 195 rows planted from different samples of healthy seed and 62 rows planted from different samples of diseased seed. Each row of 200 seeds was 30 feet long and represented a single strain or sample of seed. The record of stand of plants produced by these samples of seed appears in Table 13.

In general, the stand of plants from samples of seed with more than 10 per cent of the seed infected with *Ascochyta* spp. was considerably less than that from healthy seed. The results of tests of Alaska and Horal seed with an average infection of 18 and 12 per cent, respectively, were exceptions. The results of the tests of samples having less than 10 per cent of the seed infected with *Ascochyta* spp. showed little or no decrease in stand of plants compared with the stand from healthy seed. These results are similar to those from other tests in showing a lower percentage stand of plants from

TABLE 13.—RESULTS OF STRAIN ROW TESTS OF HEALTHY AND DISEASED SEED, CANNING CROPS FARM, GENEVA, N. Y., 1926.

VARIETY	HEALTHY SEED			DISEASED SEED*			
	Average laboratory germination	Number of strains planted†	Average stand of plants	Average laboratory germination	Number of strains planted†	Average stand of plants	Average infection of seed
	Per cent		*Per cent*	*Per cent*		*Per cent*	*Per cent*
Admiral, Green	98	44	85	97	2	69	20
Admiral, Green	—	—	—	98	4	83	8
Admiral, Yellow	97	5	82	95	1	63	18
Advancer	98	16	82	83	3	58	20
Advancer	—	—	—	97	3	77	8
Horsford	96	19	81	97	2	68	15
Horsford	—	—	—	98	19	77	5
Rice's 13	98	7	83	98	1	89	2
Perfection	97	4	81	96	1	52	26
Perfection	—	—	—	98	1	80	8
Canners' Gem	96	10	80	—	—	—	—
Premium Gem	97	8	77	—	—	—	—
Rogers K	97	10	90	98	1	91	2
Roach 49	98	1	93	95	1	67	18
Roach 49	—	—	—	97	1	89	6
Alaska	98	36	80	94	4	79	18
Alaska	—	—	—	97	8	83	4
Surprise	97	20	80	96	1	75	14
Surprise	—	—	—	97	3	74	7
Winner	98	14	89	—	—	—	—
Horal	—	—	—	97	1	88	12
Horal	—	—	—	98	3	78	3

*Results froms amples having more than 10 per cent of seed infected with *Ascochyta* spp. are shown separately from those from samples having less than 10 per cent infection.

†200 seeds per row. Each row planted with seed from a different source.

samples having a high percentage of the seed infected, while the differences obtained from samples having less than 10 per cent infected seed fall within the range of probable error of the experiments unless subjected to conditions extremely adverse for germination of the seed.

GREENHOUSE EXPERIMENTS, 1926–1927

Further tests of healthy and diseased seed were made in the greenhouse during the fall and early winter. The technic of testing was changed in that five rows of 20 seeds each were made in each flat. The rows were 3 inches apart. The seeds were spaced 1 inch

apart and covered with 1 inch of soil. Tests 160 to 171 inclusive varied from this technic in having only three rows per flat, with the first or the second row of each of three flats planted with diseased seed, while the other two rows were planted with healthy seed. Three flats with three rows of healthy seed and three flats with three rows of diseased seed were carried for comparison. The results, recorded in Table 14, show that the stand of plants from the diseased seed was consistently less than that from the healthy seed.

TABLE 14.—COMPARISON OF STAND OF PLANTS FROM HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED PLANTED IN FLATS IN GREENHOUSE, GENEVA, N. Y., 1926.*

TEST NO.	PERCENTAGE STAND OF PLANTS					
	Healthy seed			Diseased seed†		
	Row 1	Row 2	Row 3	Row 1	Row 2	Row 3
160	—	85	75	65	—	—
161	—	95	100	70	—	—
162	—	100	100	90	—	—
163	85	—	90	—	85	—
164	100	—	100	—	60	—
165	100	—	95	—	75	—
166	—	—	—	75	60	75
167	—	—	—	60	75	50
168	—	—	—	60	65	60
169	85	95	90	—	—	—
170	95	90	100	—	—	—
171	95	85	100	—	—	—
Average	93	92	94	70	70	62

*Seed planted Oct. 14. Data taken Nov. 26 when plants averaged 11 inches in height.

†Sample of seed had 21 per cent of the seed infected with *A. pisi*. Laboratory germination of the two samples of seed was 97 per cent.

Tests were made for the purpose of comparing the stand of plants from healthy seed with that from 100 per cent infected seed. Each of three flats was planted with five rows of the infected seed, and each of three other flats with five rows of the healthy seed. The sample of seed showing 100 per cent infection was obtained by selecting seed showing a diseased condition from one lot of diseased Green Admiral seed. Tests of the value of treating this diseased and healthy seed were also made in this series. The seed was planted on October 22 and the data appearing in Table 15 were taken November 23.

These data show about a 50 per cent reduction in stand from the use of 100 per cent infected seed compared with the stand from the use of healthy seed. Also, a reduction in height and vigor of the plants from the diseased seed was noted. Treatment of either

the healthy or the diseased seed with Semesan dust or Bayer 101 dust increased the stand of plants and possibly the height and vigor. The treatment of the diseased seed with the organic mercury dusts did not check the development of primary lesions of Ascochyta leaf and pod spot on the first leaves. A marked reduction in the number of plants having footrot caused by either *M. pinodes* or *A. pinodella* resulted from the treatment of diseased seed with the organic mercury dusts. As the plants were removed from the flats one month after planting, the following percentage of plants per treatment had footrot lesions: Untreated, 100; Bayer 101 treated, 8; and Semesan treated, 11. These results are similar to those obtained in previous experiments (Table 9).

TABLE 15.—RESULTS OF TESTS OF HEALTHY AND 100 PER CENT DISEASED GREEN ADMIRAL PEA SEED PLANTED IN FLATS IN THE GREENHOUSE, GENEVA, N. Y., 1926.

TREATMENT	STAND OF PLANTS PER FLAT*				AVERAGE HEIGHT OF PLANTS PER FLAT			
	I	II	III	Ave.	I	II	III	Ave.
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Inches*	*Inches*	*Inches*	*Inches*
Healthy, untreated	91	89	84	88	7.8	7.8	8.6	8.1
Healthy, Bayer 101	97	94	—	96	9.0	10.0	—	9.5
Healthy, Semesan	96	100	—	98	9.1	10.1	—	9.6
Diseased, untreated†	29	34	37	33	5.5	6.2	7.0	6.2
Diseased, Bayer 101	35	42	—	39	8.3	6.7	—	7.3
Diseased, Semesan	54	42	—	48	8.1	6.6	—	7.4

*100 seeds planted per flat in five rows, 3 inches apart; seeds 1 inch apart and covered with 1 inch of soil.

†100 per cent of seed diseased, as follows: 26 per cent with *A. pisi*, 18 per cent with *M. pinodes*, 36 per cent with *Alternaria* sp., 15 per cent with *Fusarium* sp., and 5 per cent with *A. pinodella*.

A further test of healthy and diseased seed, as well as of various treatments, was made on other samples of Green Admiral pea seed. The seed was planted in the usual manner on September 22, 1926, 100 seeds to the flat and each test in duplicate. The data relative to the stand of plants, taken on November 16, 1926, appear in Table 16.

These data show a reduced stand of plants from the diseased seed compared with that from the healthy seed. Treatment of either

healthy or diseased seed with the organic mercury dusts increased the stand of plants, with the exception of some of the treatments with Semesan Bel or Bayer 154.

TABLE 16.—RESULTS OF TESTS OF SEED TREATMENTS OF HEALTHY AND DISEASED GREEN ADMIRAL PEA SEED PLANTED IN FLATS IN THE GREENHOUSE, GENEVA, N. Y., 1926.*

TREATMENT	PERCENTAGE STAND OF PLANTS					
	Healthy seed			Diseased seed†		
	Flat I	Flat II	Average	Flat I	Flat II	Average
Control	90	90	90	78	84	81
Bayer 101	96	99	98	96	94	95
Bayer 154	100	98	99	85	83	84
Semesan	98	97	98	93	87	90
Semesan Jr.	98	100	99	86	89	88
Semesan Bel	94	92	93	79	80	80

*Laboratory germination of each sample 98 per cent.
†The diseased seed carried *A. pisi* only; 14 per cent of the seed was infected.

FIELD EXPERIMENTS, 1927

During the growing season of 1927 comprehensive field tests were made of treated and untreated lots of healthy and diseased seed. Care in planting the seed was taken in order to have the environmental factors that influence germination as uniform as possible. The seed was treated by using organic mercury dusts at the rate of 3 ounces to 1 bushel of seed and agitating in a beaker for 5 minutes. The 100 seeds in each row were uniformly spaced at 1½ inches and planted 2 inches below the surface. This uniform spacing and depth was obtained by using a board 2 inches by 2 inches with 100 holes (⅜ inch) bored thru it 1½ inches apart. For each row a trench was dug so that the top of the board was flush with the surface of the ground, and one seed was dropped into each hole. Careful removal of the board and covering of the seed gave uniform depth and spacing of the seed. When the plants were 4 to 6 inches high records of the stand of plants per row were made. The results recorded in Table 17 come from plats having 10 of the 100-seed rows spaced 7 inches apart. This rate of planting approximates a duplication of field planting at the rate of 4 to 5 bushels per acre.

The results recorded in Table 18 are from plats having four rows 1½ feet apart. The seed in two of these 100-seed rows was treated with Semesan dust, while the seed in the other two rows was untreated. Each four-row plat was planted with seed representing one lot sent in during the winter for a disease test. The soil temperature 2 inches

below the surface (Fig. 4) was obtained with a standard soil thermograph which was checked frequently with a soil thermometer. The amount of moisture in the soil was determined daily by the alcohol method described by Bouyoucos (1927). The samples of soil to be tested were taken from the same five representative parts of the field each day at the same hour. The daily averages of these five determinations are expressed in percentage of moisture-holding capacity of the soil in Fig. 4. The rainfall records in Fig. 4, from the weather records of this Station, were taken about ½ mile from the experimental plats. The soil in the experimental plat was a fairly heavy Ontario loam. The plats sloped to the south with good water drainage.

In the 1,000-seed plats (Table 17) the comparison of healthy and diseased seed of the Green Admiral and Perfection varieties in each case showed a greater stand of plants from the healthy seed. The treatment of these wrinkled varieties with organic mercury dusts considerably increased the stand of plants from both the diseased and the healthy lots of seed. Treatments of seed of the Alaska variety generally showed beneficial results. The greater stand of plants from the untreated Alaska seed compared with the stand from untreated wrinkled varieties, and the smaller benefits from treatment of Alaska seed, appear to be due mainly to two factors, *viz.*, the greater hardiness of Alaska variety seed and the more favorable soil moisture and temperature conditions prevailing at the time of planting (Fig. 4).

The data from the row tests (Table 18) also show only slight differences in results from the use of healthy and diseased seed of the Alaska variety, with a consistent slight benefit from treatment with the organic mercury dust. With wrinkled varieties the stand of plants from the lots of healthy seed was in general markedly greater than that from the lots of diseased seed. Considerable benefit was obtained from the treatment of either diseased or healthy seed of the wrinkled varieties with the organic mercury dust. The beneficial results from the use of healthy seed and from the treatment of either healthy or diseased seed were greatest with the Green Admiral variety. These data show that the presence of any of several organisms in the interior of the seed may lower the vitality of the seed and account for a decrease in stand of plants, especially under soil conditions unfavorable for the germination of pea seed. It is shown further that laboratory germination test records based on

TABLE 17.—RESULTS OF FIELD TESTS OF VARIOUS SEED TREATMENTS OF HEALTHY AND DISEASED PEA SEED, GENEVA, N. Y., 1927.

TREATMENT	AVERAGE STAND OF PLANTS PER ROW IN EACH PLAT*											
	Alaska				Green Admiral				Perfection			
	Seed healthy		Seed healthy		Seed healthy		Seed diseased†		Seed healthy		Seed diseased‡	
	Per cent	P.E.M§	Per cent	P.E.M	Per cent	P.E.M	Per cent	P.E.M	Per cent	P.E.M	Per cent	P.E.M
Control	69	1.35	73	1.09	56	1.30	22	1.34	57	0.88	49	1.35
Bayer dust	76	1.57	74	0.69	66	1.58	37	2.30	69	1.33	66	0.85
Dip-dust	79	0.87	77	1.14	75	1.10	43	1.56	77	1.11	69	1.07
Bayer 154	78	2.28	77	1.11	69	1.74	39	1.35	63	1.56	66	1.37
Bayer 101	81	0.65	83	0.91	81	0.89	42	0.87	70	1.34	58	1.07
Semesan	83	0.89	84	1.61	79	1.08	49	1.08	85	1.06	61	0.86
Semesan Jr.	74	0.87	81	1.18	71	1.07	45	1.10	69	1.30	62	1.38

*Average stand per row, 10 rows of 100 seeds each. Rows 7 inches apart. Seeds 2 inches below the surface and 1½ inches apart in rows. Laboratory tests according to seed analysts' methods showed each lot of seed as germinating 96 to 98 per cent.

†Seed 30 per cent diseased, as follows: 26 per cent *A. pisi*, 3 per cent *Alternaria* sp., and 1 per cent *Fusarium* sp.

‡Seed 22 per cent diseased, as follows: 13 per cent *A. pisi*, 6 per cent *Alternaria* sp., and 3 per cent *Fusarium* sp.

§P.E.M = probable error of the mean, $\frac{0.6745 \times SD}{\sqrt{N}}$.

TABLE 18.—RESULTS OF FIELD TESTS OF HEALTHY AND DISEASED PEA SEED, GENEVA, N. Y., 1927.

VARIETY	SAMPLE No.	STAND OF PLANTS*						SEED INFECTED WITH FUNGOUS ORGANISMS†						LABORATORY GERMINATION‡	WHERE SEED WAS PRODUCED
		Untreated			Semesan treated										
		Row 1	Row 2	Average	Row 3	Row 4	Average	Total	*A. pisi*	*M. pinodes*	*A. pinodella*	*Fusarium* spp.	*Alternaria* sp., other fungi		
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
Alaska	18	69	66	68	72	79	76	0	—	—	—	—	—	98	Michigan
Alaska	22	75	82	79	85	90	88	0	—	—	—	—	—	99	Idaho
Alaska	27	63	67	65	82	75	79	0	—	—	—	—	—	98	Montana
Alaska	37	69	76	73	76	82	79	0	—	—	—	—	—	99	E. Washington
Alaska	40	67	72	70	81	82	82	0	—	—	—	—	—	98	E. Washington
	Average			71			81								
Alaska	34	68	76	72	88	81	85	2	—	—	—	2	—	96	E. Canada
Alaska	17	68	77	73	81	75	78	4	—	—	2	—	2	98	Wisconsin
Alaska	21	85	79	82	78	84	80	4	4	—	—	—	—	99	Wisconsin
Alaska	24	81	72	77	86	84	85	4	—	2	2	—	—	99	Wisconsin
Alaska	33	79	75	77	75	84	80	4	—	2	—	—	2	97	E. Canada
Alaska	35	68	61	65	70	65	68	4	2	—	—	2	—	99	E. Canada
Alaska	15	60	70	65	69	68	69	6	4	—	—	—	2	98	Wisconsin
Alaska	23	78	47	63	70	81	76	6	—	6	—	—	—	99	Wisconsin
Alaska	26	72	77	75	90	88	89	6	4	2	—	—	—	97	Wisconsin
Alaska	19	65	70	68	77	84	81	8	—	2	4	—	2	98	Wisconsin
Alaska	20	65	76	71	86	88	87	8	6	—	—	2	—	98	Wisconsin
Alaska	25	94	75	85	86	87	87	8	4	—	—	—	4	98	Wisconsin
Alaska	36	84	78	81	91	84	88	8	4	—	—	2	2	98	Wisconsin
	Average			73			81								

Alaska	17	92	80	86	86	88	87	10	6	2	—	—	2	99	Wisconsin
Alaska	31	58	62	60	67	78	73	12	8	—	—	—	2	99	Wisconsin
Alaska	39	70	62	66	72	73	73	12	4	—	4	2	2	97	Wisconsin
Alaska	30	59	68	64	71	71	71	14	10	—	—	2	2	96	Wisconsin
Alaska	38	65	64	65	70	83	77	14	10	—	—	—	4	98	Wisconsin
Alaska	28	53	43	48	57	55	56	20	4	—	9	—	7	95	Wisconsin
Alaska	29	72	54	63	65	69	67	20	10	5	—	4	1	96	Wisconsin
Alaska	32	68	76	72	70	81	76	22	16	—	—	—	6	96	Wisconsin
Alaska	41	75	68	72	78	80	79	22	—	14	6	—	2	98	Wisconsin
	Average			66			73								
Green Admiral	64	56	53	55	67	74	71	0	—	—	—	—	—	97	Montana
Green Admiral	67	60	45	53	67	73	70	0	—	—	—	—	—	98	Idaho
	Average			54			71								
Green Admiral	76	52	41	47	65	75	70	6	4	—	—	—	2	96	Wisconsin
Green Admiral	61	24	47	36	58	40	49	9	6	—	—	—	3	97	Michigan
Green Admiral	42	33	37	35	51	50	51	14	4	—	6	2	2	92	Michigan
Green Admiral	57	29	38	34	39	34	37	16	12	—	—	2	2	97	E. Canada
Green Admiral	58	28	34	31	46	39	43	16	14	2	—	—	—	99	E. Canada
Green Admiral	59	23	20	22	38	25	32	16	10	4	—	—	2	98	E. Canada
Green Admiral	68	17	15	16	52	31	42	17	17	—	—	—	—	94	E. Canada
Green Admiral	63	54	60	57	68	60	64	18	8	—	4	4	2	94	New York
Green Admiral	72	26	14	20	37	25	31	18	18	—	—	—	—	94	E. Canada
Green Admiral	60	19	35	27	48	44	46	20	18	—	—	2	—	96	E. Canada
Green Admiral	66	30	24	27	37	18	27	20	20	—	—	—	—	96	E. Canada
Green Admiral	62	24	22	23	39	32	36	22	14	4	—	—	4	96	E. Canada
Green Admiral	69	10	11	11	22	34	28	23	23	—	—	—	—	96	E. Canada
Green Admiral	65	24	34	29	44	22	33	26	26	—	—	—	—	95	E. Canada
Green Admiral	70	35	30	33	45	39	42	26	26	—	—	—	—	95	E. Canada
Green Admiral	77	30	38	34	46	48	47	26	26	—	—	—	—	95	E. Canada
Green Admiral	71	38	35	37	45	38	42	27	27	—	—	—	—	96	E. Canada
Green Admiral	73	20	12	16	19	23	21	28	28	—	—	—	—	97	E. Canada
Green Admiral	78	38	22	30	41	37	39	29	29	—	—	—	—	93	E. Canada
Green Admiral	74	16	22	19	41	42	42	30	30	—	—	—	—	96	E. Canada
Green Admiral	75	18	12	15	29	19	24	30	26	—	—	2	2	95	E. Canada
Green Admiral	79	10	14	12	24	15	20	30	30	—	—	—	—	95	E. Canada
	Average			28			39								

TABLE 18—*Concluded.*

VARIETY	SAMPLE NO.	STAND OF PLANTS*						SEED INFECTED WITH FUNGOUS ORGANISNS†						LABORATORY GERMINATION‡	WHERE SEED WAS PRODUCED
		Untreated			Semesan treated										
		Row 1	Row 2	Average	Row 3	Row 4	Average	Total	*A. pisi*	*M. pinodes*	*A. pinodella*	*Fusarium* spp.	*Alternaria* sp.; other fungi		
Yellow Admiral	82	73	80	77	90	86	88	4	4	—	—	—	—	98	Michigan
Yellow Admiral	84	71	82	77	83	91	87	4	—	4	—	—	—	98	Michigan
Yellow Admiral	87	70	71	71	81	72	77	4	2	—	—	—	2	97	Michigan
Yellow Admiral	85	66	60	63	82	81	82	10	8	2	—	—	—	95	Michigan
Yellow Admiral				71			83								
Yellow Admiral	83	55	54	55	74	70	72	18	12	—	2	2	2	96	Michigan
Yellow Admiral	86	64	56	60	63	67	65	20	16	—	—	—	4	95	Michigan
Yellow Admiral	80	59	52	56	73	64	69	24	18	4	—	—	2	83	Michigan
Yellow Admiral	81	34	43	39	64	57	61	28	28	—	—	—	—	82	Michigan
	Average			52			67								
Perfection	89	44	56	50	71	74	73	0	—	—	—	—	—	96	Idaho
Perfection	106	82	66	74	77	70	74	0	—	—	—	—	—	98	Idaho
Perfection	113	80	79	80	82	75	79	0	—	—	—	—	—	97	Idaho
Perfection	116	64	59	62	83	72	78	0	—	—	—	—	—	97	Idaho
	Average			67			76								

Perfection	90	66	69	68	78	79	79	2	2	—	—	—	—	97	Michigan
Perfection	88	37	44	41	37	39	38	6	4	—	—	—	2	95	Michigan
Perfection	117	24	33	29	59	53	56	6	6	—	—	—	—	90	Michigan
Perfection	115	57	55	56	70	70	70	12	8	—	2	—	2	95	Michigan
Perfection	118	58	53	56	65	67	66	12	8	—	2	—	2	95	Michigan
Perfection	107	43	47	45	61	61	61	16	14	2	—	—	—	95	Michigan
Perfection	108	67	64	66	70	74	72	18	—	16	—	—	2	95	Michigan
Perfection	111	65	66	66	71	74	73	18	—	16	—	—	2	95	Michigan
Perfection	112	74	72	73	79	70	75	18	8	6	—	4	—	96	Michigan
Perfection	114	31	26	29	31	33	32	24	4	16	—	—	4	91	Michigan
Perfection	91	71	73	72	86	84	85	28	10	14	—	2	2	95	Michigan
Perfection	110	25	16	21	23	30	27	28	2	16	—	2	8	84	Michigan
Perfection	109	27	22	25	48	55	52	30	6	18	4	—	2	95	E. Canada
	Average			50			60								
Surprise	119	53	55	54	61	63	62	0	—	—	—	—	—	97	E. Washington
Surprise	120	82	74	78	81	70	76	0	—	—	—	—	—	97	Michigan
Surprise	121	76	66	71	75	82	79	0	—	—	—	—	—	99	Idaho
Surprise	122	61	55	58	75	80	78	0	—	—	—	—	—	96	Montana
Surprise	123	61	66	64	80	79	80	0	—	—	—	—	—	97	Montana
	Average			65			75								
Horsford	125	65	67	66	69	86	78	0	—	—	—	—	—	97	Idaho
Horsford	126	63	67	65	75	78	77	0	—	—	—	—	—	96	Idaho
Horsford	131	67	58	63	75	52	64	0	—	—	—	—	—	98	Idaho
Horsford	132	62	73	68	69	75	72	0	—	—	—	—	—	96	Idaho
	Average			65			72								
Horsford	124	51	51	51	68	73	71	2	—	2	—	—	—	98	E. Canada
Horsford	128	47	51	49	63	73	68	2	—	2	—	—	—	98	E. Canada
Horsford	129	72	84	78	78	86	82	4	2	2	—	—	—	93	Michigan
Horsford	127	58	64	61	67	62	65	18	10	—	2	—	6	92	Michigan
Horsford	130	43	50	47	63	62	63	18	14	—	—	—	4	93	Michigan
Horsford	133	64	71	68	82	74	78	22	12	8	—	—	2	92	Michigan
	Average			59			71								

*Seed planted 100 per row, 2 inches deep and 1½ inches apart, on the following dates: Alaska, May 6; Green Admiral, May 13; Yellow Admiral, May 14; Perfection, Surprise, and Horsford Market Garden, May 19. See Fig. 4.

†Results of laboratory tests. See pages 14 to 17.

‡Laboratory germination tests of 100 seeds per sample, according to seed analysts' methods.

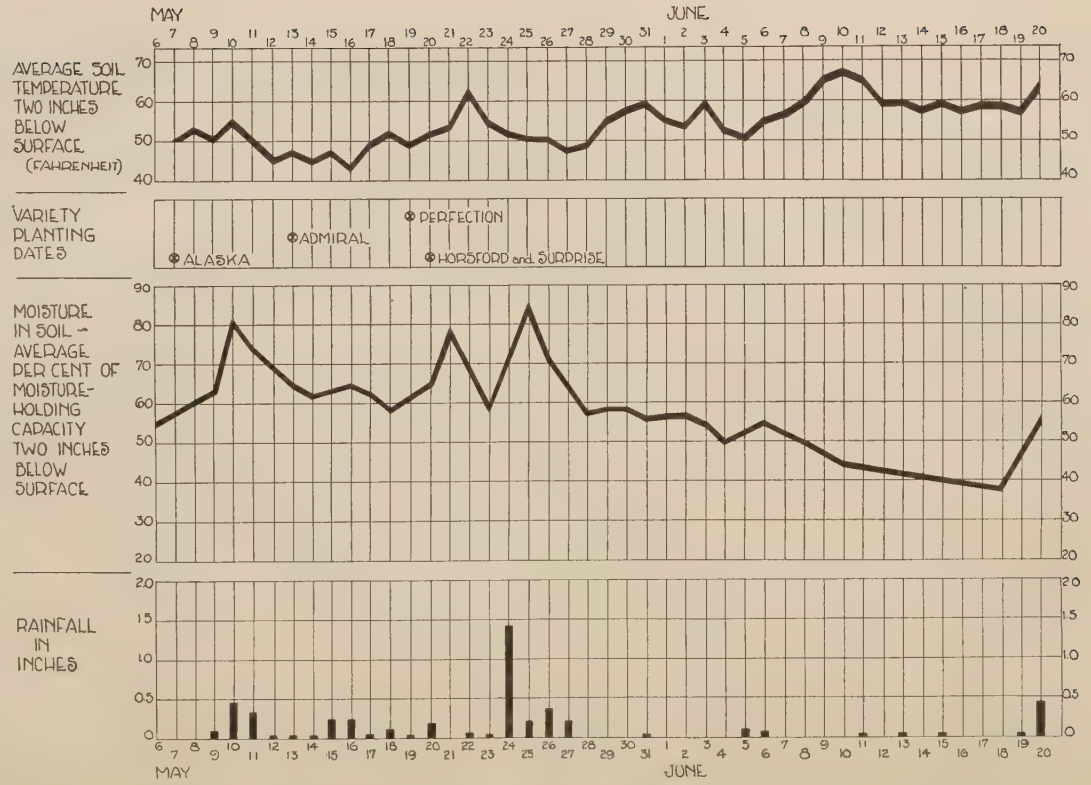

FIG. 4.—A GRAPHIC SUMMARY OF CERTAIN RECORDS RELATING TO RESULTS OF FIELD TESTS OF HEALTHY AND DISEASED PEA SEED, GENEVA, N. Y., 1927. (See page 32.)

the percentage of seed viable are, in general, of no value as indicators of the presence of fungous organisms in pea seed.

The results of these experiments are similar to those of previous tests in that seed of the Alaska variety showed greater hardiness than seed of the wrinkled varieties. The use of diseased compared with healthy Alaska seed has given smaller differences in percentage stand than those obtained in comparative tests with healthy and diseased seed of wrinkled varieties. The benefit derived from the treatment of Alaska seed with organic mercury dusts has been consistently less than that obtained from similar treatment of seed of the wrinkled varieties.

Treatment of the seed with the organic mercury dusts appeared to have no deterrent effect on the spread of *A. pisi* from diseased seed to the above-ground parts of the plants. This is shown by data obtained on the 1,000-seed plats of treated and untreated diseased Green Admiral seed. Counts were made of the number of plants showing primary lesions of *A. pisi* on the foliage soon after the plants had emerged from the soil. These data show that the following number of plants per plat had primary lesions developing from diseased seed: Control, 7; Bayer 154, 10; Bayer 101, 13; Semesan, 16; Semesan Jr., 16; Bayer dust, 15; and Bayer Dipdust, 12. The greater number of plants with primary lesions in the treated-seed plats may be explained by the increased stand of plants in these plats resulting from the treatment of the seed. These data and similar data obtained in other field trials confirm results obtained in greenhouse trials. Treatment of seed infected with *M. pinodes* or *A. pinodella* appeared to reduce materially the amount of footrot injury as well as the amount of injury from soil-borne *Rhizoctonia* sp. Further investigations are being conducted on this subject.

RESISTANT VARIETIES

In order to ascertain whether any varieties of peas were resistant to attack by *Ascochyta* spp., controlled inoculation trials were made. Seventy-two series of inoculations were made on 25 to 100 plants of 8 or 16 varieties or strains of peas in each series. The Green Admiral, representing a variety very susceptible to injury by these organisms, and the Horsford, which showed the least injury, were carried in each inoculation trial as standards for determining the relative susceptibility of other varieties.

The greenhouse inoculations were made during the winter of 1926–27. The plants used in the greenhouse trials were grown in

flats (15 x 21 x 4 inches) of soil. The inoculations were made by atomizing a suspension of pycnospores in water (4 to 6 spores per high-power field on glass slide) on the plants and placing them in a moist chamber for 24 hours. Control flats of plants were atomized with sterile distilled water and carried comparatively.

The field inoculations were made on plats 5 feet square, each containing 8 or 16 varieties and 50 or 25 plants per variety. Three plats, all containing the same varieties, were run comparatively in each trial. One of the three plats was inoculated with a water suspension of pycnospores of one organism, another plat with a water suspension of pycnospores of another organism, and the third plat was atomized with sterile distilled water as a control. A high moisture content over the plats was maintained for 24 hours by covering them with pyramidal canvas-covered structures on which water was sprayed continuously (Plate VI). The canvas was stretched over wooden frames, the structures being connected in a series by short lengths of hose. A spray nozzle attached to a pipe that extended about 1 foot above the apex of each structure and connected by a hose to the city water system gave a spreading spray of water that kept the canvas wet. These inoculation chambers were easily moved from one plat to another and were very effective in maintaining sufficient moisture for the development of the disease.

The pycnospores used in the inoculations were produced on oat agar slants. The spores were washed from 10- to 14-day-old cultures that had been incubated at 18°C.

In the greenhouse and field experiments the following strains of the organisms were used: *M. pinodes* isolated from seed harvested in New York, Canada, and Wisconsin; *A. pisi* isolated from seed harvested in Canada, England, New York, and Wisconsin; *A. pinodella* isolated from seed harvested in New York, Wisconsin, and Idaho.

After each inoculation data were taken as to the number and severity of lesions per plant produced on stem and leaves. Records on dead plants and on height of living plants were taken near the end of the growing period. These data were summarized and the varieties showing slight, moderate, or severe injury from attacks by *M. pinodes* or *A. pisi* are shown in Table 19. Slight injury is used to designate injury to the plants that would probably reduce the crop 10 to 30 per cent; moderate injury would probably give a

TABLE 19.—AVERAGE DEGREE OF INJURY NOTED IN TESTS TO DETERMINE THE SUSCEPTIBILITY TO INJURY OF PEA VARIETIES AND STRAINS WHEN INOCULATED WITH *M. pinodes* OR *A. pisi*, GENEVA, N. Y.*

Mycosphaerella pinodes			*Ascochyta pisi*		
Slight	Moderate	Severe	Slight	Moderate	Severe
‡Admiral 17.78 (5)	‡Acme (5)	‡Alaska, Double (5)	‡Acme (5)	Canadian Beauty (2)	Admiral, Green (72)
Advancer (6)	Alderman (4)	‡Alcross (5)	‡Admiral 17.78 (5)	Canners' Gem (7)	Admiral Yellow (4)
‡Badger Special (5)	‡Ashford 17.106 (5)	Arthur (2)	Advancer (8)	Early Britain (2)	‡Admiral 17.83 (5)
‡Badger 20.140 (5)	‡Badger 31.14 (5)	Bangalia (2)	Alderman (4)	English Field (2)	Alaska (22)
Champion of England (4)	Bliss Abundance (4)	Canada Field (2)	‡Ashford 17.106 (5)	Gradus (4)	‡Alaska, Double (5)
Golden Vine (5)	‡Horal 11.15 (5)	Canadian Beauty (2)	‡Badger Special (5)	‡Horal 11.15 (5)	‡Alcross (5)
‡Horal (4)	‡Horal 22.53 (5)	Canners' Gem (8)	‡Badger 20.140 (5)	‡Horal 22.53 (5)	Arthur (2)
Horsford (72)	Hundredfold (2)	Chancellor (2)	‡Badger 31.14 (5)	Hundredfold (4)	Bangalia (2)
Perfection (7)	Little Gem (5)	Chang (2)	Bliss Abundance (4)	MacKay (2)	Cana a Field (2)
	Premium Gem, Carter's (5)	Cloverland (2)	Champion of England (4)	Nott's Excelsior (4)	Chancellor (2)
	Rice's 13 (6)	Duke of Albany (4)	Cloverland (2)	Premium Gem, Carter's (7)	Chang (2)
	Telephone (4)	Early Britain (2)	Horsford (72)	Prussian Blue (2)	Duke of Albany (4)
		English Field (2)	‡Horsford 10.452 (5)	Telephone (4)	First and Best (4)
		First and Best (2)	Little Gem (5)	Telephone, Dwarf (4)	Golden Vine (2)
		Gradus (4)	Perfection (8)		‡Horal (3)
		‡Horsford 10.452 (2)	Scotch peas (2)		‡Hustler (5)
		‡Hustler (5)			Little Marvel (4)
		Little Marvel (4)			Laxtonian (4)
		Laxtonian (4)			Marrowfat (2)
		MacKay (2)			Multiplier (2)
		Marrowfat (2)			‡Primal (5)
		Multiplier (4)			Rice's 13 (8)
		Nott's Excelsior (4)			Rogers K (5)
		‡Primal (5)			Surprise (9)
		Prussian Blue (2)			Thomas Laxton (4)
		Rogers K (6)			Winner (6)
		Scotch peas (2)			
		Surprise (11)			
		Telephone, Dwarf (4)			
		Thomas Laxton (4)			
		Winner (7)			

Severe
Admiral, Green (72)
Admiral, Yellow (4)
‡Admiral 17.83 (5)
Alaska (21)

*All trials with market garden and field peas were conducted in the field (Plate VI). Trials with canning varieties and strains were conducted in field and greenhouse, Geneva, N. Y., 1926 to 1927. See pages 39 to 40 for details of methods used. Numbers in parentheses represent the number of inoculation trials made on the variety or strain.

‡New strains and varieties developed by E. J. Delwiche, University of Wisconsin, Madison, Wisc. All other canning varieties and strains represent lots of seed used in the trade as furnished by leading seedsmen. All field pea varieties were furnished by John H. Barron, Cornell University, Ithaca, N. Y.

reduction of 30 to 65 per cent of the crop; and severe injury would probably reduce the crop 65 to 100 per cent.

No varieties of peas were found to be immune to infection by the Ascochyta organisms tested. Certain varieties, however, were considerably less susceptible than others. The Horsford Market Garden variety appeared to be the most resistant to injury from the three organisms. This was especially noticeable in its resistance to basal stem-rot caused by *M. pinodes*. The varieties or strains that showed only slight susceptibility to injury from both *M. pinodes* and *A. pisi* are as follows: Admiral 17.78, Advancer, Badger Special, Badger 20.140, Champion of England, Horsford, and Perfection.

No difference in virulence was noted in the strains of *M. pinodes* isolated from seed harvested in New York, Canada, or Wisconsin.

A marked difference in susceptibility of certain varieties to attack by different isolations of *A. pisi* was noted. The isolations from Canada and England caused less injury on Green Admiral, Yellow Admiral, Alderman, Bliss Abundance, Canners' Gem, Hundredfold, Nott's Excelsior, and Dwarf Telephone and more injury on Gradus, Little Marvel, Carter's Premium Gem, Horsford, and Rice's 13 than did the isolations from seed harvested in New York and Wisconsin.

The inoculation trials with *A. pinodella* showed that it was a more virulent basal stem-rot producing organism than *M. pinodes*, and that when it was used as inoculum the difference in susceptibility of the varieties of peas was not as marked as it was when *M. pinodes* was used. Advancer, Horsford, Perfection, and Rice's 13 showed less injury from attacks by *A. pinodella* than did Green Admiral, Alaska, Carter's Premium Gem, and Surprise. No difference in virulence was noted in the strains of *A. pinodella* isolated from seed harvested in New York, Wisconsin, or Idaho.

Strains of Green Admiral, Advancer, Alaska, Canners' Gem, Horsford, Perfection, Rice's 13, and Surprise from various seed dealers were used in the inoculation trials. The strains of a given variety from different sources did not differ materially in degree of susceptibility to injury when attacked by the various organisms.

Observations on the development of Mycosphaerella blight in the field have substantiated some of the results of the inoculation trials. It has been noted that plantings of Horsford, Advancer, and Perfection varieties were only slightly damaged by this disease, especially in 1925, while Admiral, Surprise, Rogers K, and Winner in adjacent plantings were very seriously damaged.

SUMMARY AND CONCLUSIONS

A study of the literature and the present investigations lead to the conclusion that three organisms may be associated with the diseased condition of peas previously known as Ascochyta leaf and pod spot or Ascochyta blight.

It is proposed that the three diseases be designated as Ascochyta leaf and pod spot (*Ascochyta pisi* Lib.), Mycosphaerella blight (*Mycosphaerella pinodes* (Berk. and Blox.) Stone), and Ascochyta footrot (*Ascochyta pinodella* n. sp.).

The light-tan, marginate spots on the host caused by *A. pisi* infections differ markedly from the purplish-brown, irregular lesions caused by infections by the other two organisms. Cultural characteristics of the three organisms differ. This difference is the most pronounced in the comparison of *A. pisi* cultures with those of the other two organisms. Pycnospores of *A. pisi* and of *M. pinodes* are distinctly larger than those produced by *A. pinodella*. An ascigerous stage has been found in culture and on the host in association with *M. pinodes*. Mature ascospores may be found on pea refuse and are also produced on dead parts of growing plants in as short a period as 13 days after inoculation.

The period of incubation on the host from inoculation to the appearance of macroscopic lesions was two to four days for *M. pinodes* and *A. pinodella* and 6 to 8 days for *A. pisi*.

The new species *Ascochyta pinodella* is described.

Mycosphaerella blight is the most destructive of the three diseases in New York. A study of the literature shows that this disease has probably been the most destructive of the three in the serious outbreaks of the disease formerly known as Ascochyta blight.

All three organisms may live over winter in pea refuse and spread to new plantings in the spring. *A. pinodella* appears to be able to live in the soil for at least two years after it is introduced in a pea crop. For these reasons it is advisable that pea growers practice a system of cultivation to destroy pea refuse, and rotate crops so that peas are not grown on the same area more than once in four or five years.

Recent investigations throw uncertainty upon conclusions drawn from previous work on the host range of *A. pisi*. Further investigation is desirable in order to determine the host range of these organisms in relation to the introduction and spread of the diseases in pea plantings.

The three species of Ascochyta are often carried in the seed, and their presence may be determined by laboratory tests. A large

number of samples of pea seed harvested in 1924, 1925, and 1926 were tested to determine viability and disease content. These tests showed that seed produced in the semi-arid western part of the United States was practically always free from fungous infection, while a high percentage of the seed produced in eastern North America was more or less infected.

It is possible and would seem advisable for seed analysts to include in their pea seed germination reports data on the percentage of seed per sample infected with fungous organisms, especially with *Ascochyta* spp.

Tests of healthy and diseased pea seed were made in soil under greenhouse and field conditions. Seed infected with fungous organisms usually gave a lower percentage stand of plants than did healthy seed. This difference was greater when a high percentage of the seed was infected and when the seed was planted under soil conditions of high moisture content and low temperature.

The use of seed infected with *Ascochyta* spp. introduces the organisms into new plantings in a position very favorable for their spread during the growing season. In seasons having prolonged and timely rains the diseases may develop to a destructive extent, while in seasons or climates with less rainfall little development of the diseases may be noted.

Under the growing conditions prevailing in New York, it is advisable to use seed that is free from these disease-producing organisms. It is possible to obtain seed free from these organisms from the semi-arid seed-producing areas of the western part of the United States or to determine by laboratory tests whether any lot of seed is infected with *Ascochyta* spp.

In general, the treatment of pea seed with organic mercury dusts has increased the percentage stand of plants. The amount of this increase was variable, being greater on seed of low vitality and when seed was planted under soil conditions of high moisture content and low temperature. It appears that the treatment of pea seed with organic mercury dusts will usually increase the stand of plants sufficiently to justify their use under soil conditions that prevail at planting time in New York.

In these experiments the use of organic mercury dusts on seed infected with *A. pisi* did not control primary infection from diseased seed to the above-ground parts of the plant. Preliminary experiments tend to show that treatment of seed infected with *M. pinodes* or *A. pinodella* is of considerable benefit in reducing footrot injury.

From the results of these experiments and observations the use of healthy seed in preference to treated diseased seed is recommended.

A large number of inoculation trials on peas, including canning, market garden, and field varieties were made. No variety used in the trials proved to be immune to attack by any of the organisms, altho some varieties were very much more susceptible to injury than others. The use of the less susceptible varieties where adaptable, as well as development of new varieties from them, may considerably reduce losses from these diseases.

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